Astrobiology Small Payloads

Proposal Information Package

Executive Version

February 21, 2008

Astrobiology Small Payloads (ASP) offers access to the space environment to a multi-disciplinary community to perform research relevant to Astrobiology goals <http://astrobiology.arc.nasa.gov/roadmap> by supporting the development of spaceflight experiments and associated hardware built upon a proven spacecraft platform. By using and later expanding upon capabilities provided by the triple cube nanosatellite platform and a suite of existing payload instruments and components, investigators are given the opportunity to propose research in the fields of exobiology, astrochemistry / planetary science, and astrophysics on small spacecraft missions that are managed utilizing demonstrated processes, proficient teaming arrangements, and that promise rapid return of data.

The ASP offers flexibility in terms of investigator selected partnering arrangements with existing spacecraft, payload, and integration providers, examples of which are provided for reference in this Proposal Information Package (PIP). Regardless of other teaming arrangements, launch vehicle accommodations, final acceptance testing, and mission operations will be performed and managed by NASA Ames Research Center (ARC) through the Small Spacecraft Division (SSD). Additional information on each of the topics mentioned above is provided in the following sections of this PIP.

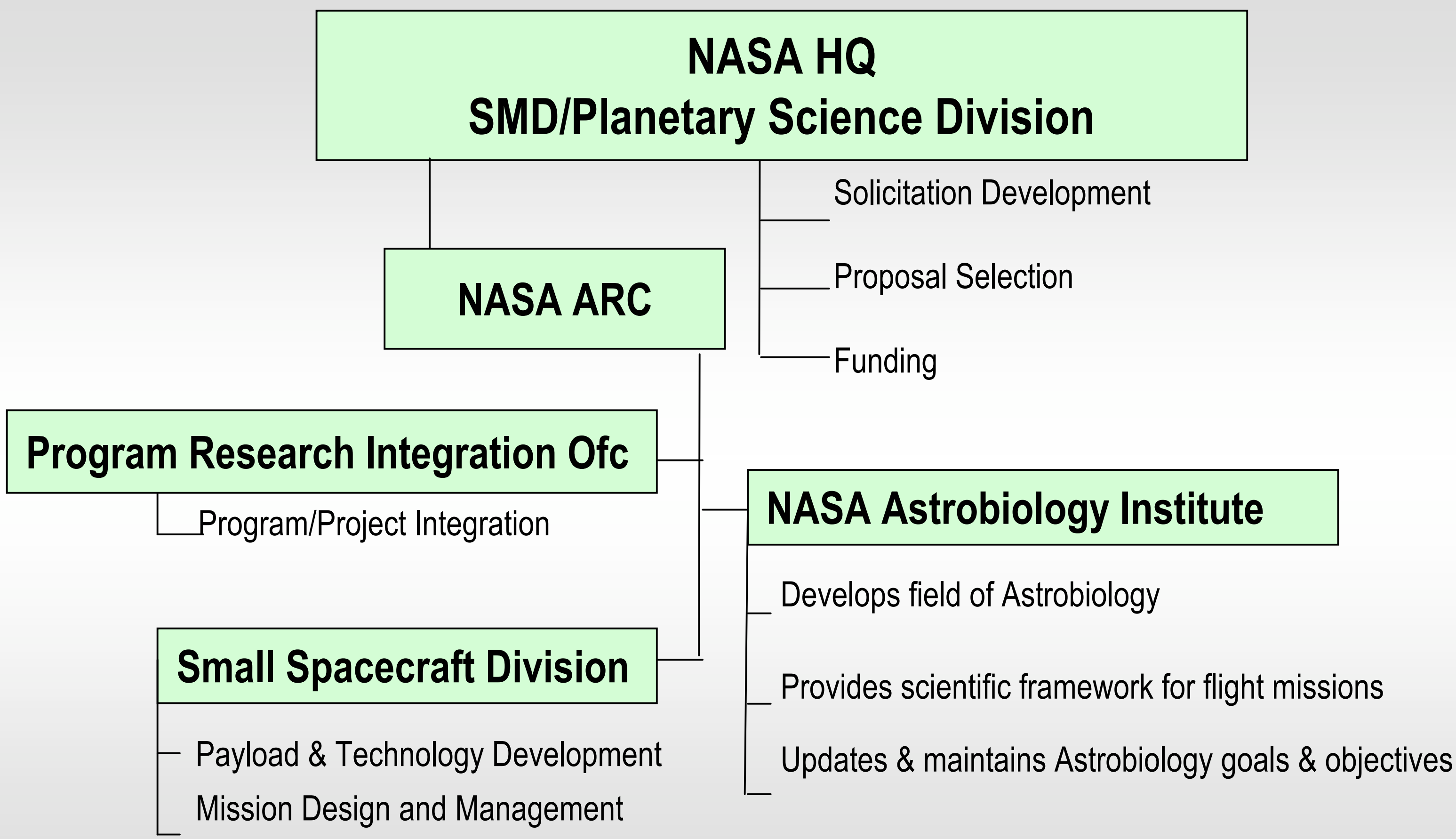
The scientific goals of ASP investigations will be facilitated through achievement of established ASP top-level objectives:

1. Support investigator-defined science mission and payload requirements in pursuit of identified Astrobiology objectives.
2. Provide opportunities to design, develop, integrate, and expand upon payload instrumentation - demonstrate the advantages of small platforms for ASP research by developing and integrating small subsystems requiring minimal resources (power, mass, volume).
3. Identify and coordinate nano- and micro-satellite technologies and related launch opportunities that will provide alternative low cost access to space.
4. Conduct appropriate nanosatellite and/or microsatellite spaceflight missions to accomplish NRA-solicited, PI-directed missions.
5. Establish collaborations and partnerships that will contribute to and utilize the demonstrated payload and platform capabilities and will lead to significant cost-shared flight opportunities with partners from other parts of NASA, academia, industry and other government agencies.

Several key organizations are involved in different aspects of providing opportunities for ASP investigations. The **Planetary Science Division** within the Science Mission Directorate at NASA Headquarters (HQ) develops solicitations directed toward achieving overall Astrobiology goals as established by the **Astrobiology Institute**; determines final proposal selection, and provides funding for selected proposals. The **Program Research Integration Office** (PRIO) at NASA ARC provides support to HQ in each of these areas by providing a program-project integration function that includes the coordination of technology working groups chartered to define technology roadmaps for use in the development of programmatic solicitations and PIPs to help meet the needs of Astrobiology research; coordination of Engineering, Cost, and Management reviews of proposals as assigned by NASA HQ; and assistance in the final integration of the solicitation and proposal review process to support final selection by NASA Headquarters. Post-selection PRIO activities may include grant and contract allocation, technical project monitoring and reporting, education and outreach coordination, and systems engineering and integration functions as applicable. The **Small Spacecraft Division** at NASA ARC provides a range of capabilities and services to include provision of spacecraft platform; complete development, integration, and testing of payload components; and launch vehicle accommodations, final acceptance testing, and mission operations.

Figure I.C-1 illustrates the ASP organization.

Figure I.C.-1 ASP Organization

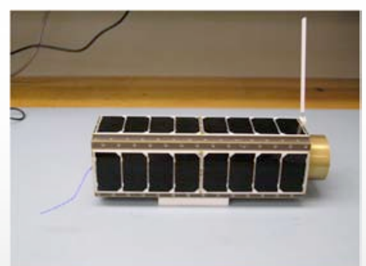


Overview - Several current and planned opportunities for participation in solicited ASP activities will be afforded the community in the near future in a variety of involvement levels. The ASTID call for concept studies is an initial step toward opportunities to access space.

Collaborative Opportunities - Opportunities to partner with other researchers, instrument and payload developers and integrators, launch providers, and other groups on Astrobiology calls of interest are facilitated by periodic workshops and community notices.

Missions of Opportunity (MoO) - Opportunities to fly Astrobiology investigations using exiting instruments on a ready-to-fly status will make use of immediate launch opportunities.

1U CubeSat – Pumpkin, Inc



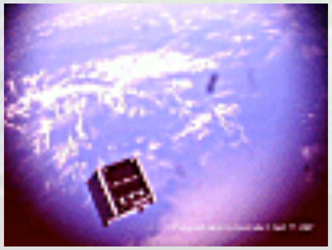
3U CubeSat – NASA ARC

Poly-PicoSat Orbital Deployer (P-POD)

The ASP Workshop was held June 18 – 20, 2007 at NASA Ames Research Center. It was convened to solicit experiment concepts from the external science community and to further discuss and justify small satellites as an appropriate platform for Astrobiology science. The workshop was structured to facilitate information exchange between the science and engineering communities, resulting in science concepts vetted with respect to development timeframes and possible launch opportunities. A total of 29 different mission concepts were considered during the following individual group sessions: *Remote/Observational, Pre-Biotic chemistry and Planet Formation (Gas-Grain Particle Interactions), Organics in Space, and Biology*. These concepts each include the science objective and instrument and platform types. They are summarized in Table 1.0-1 Mission Concepts Considered by the Workshop in the Executive Summary and Science Opportunity Summary sections of the ASP Workshop Report available at http://nai.arc.nasa.gov/asp

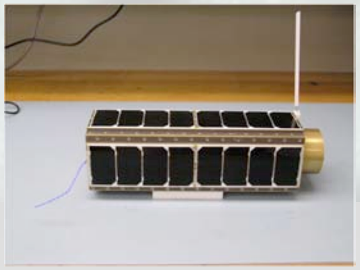
IV. Spacecraft, Payload / Instrument Development and Management

A. Spacecraft Platforms



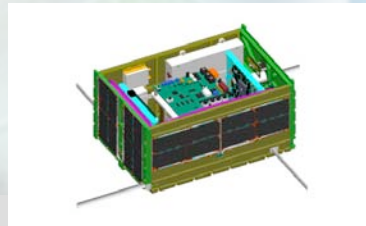
Boeing Co./Cal Poly SLO

1U Cubesat



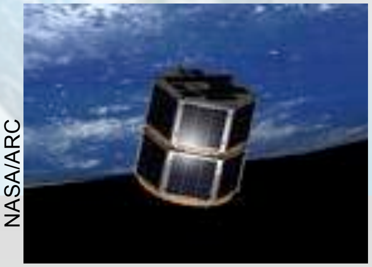
NASA/ARC

3U Cubesat



6U Nanosat*

NASA/ARC



University Nanosat*

Univ. Texas Austin

NASA/ARC

Remote Sensing Sat*

Satellite	Mass (kg)	Power (W)	Example
1U Cubesat	1	~2	Various Universities (http://www.cubesat.org/); Pumpkin Inc. (http://www.cubesatkit.com/)
3U Cubesat	5	4	GeneSat-1 (NASA/ARC)
6U Cubesat*	10	20	*Conceptual*
University Nanosat*	35	40-60	*Conceptual* FASTRAC (University of Texas Austin, http://fastrac.ae.utexas.edu/news/recent.php)
Remote Sensing Sat*	50	40-60	*Conceptual*

** Not currently available. Conceptual designs or missions in development. For reference, only.*

IV. Spacecraft, Payload / Instrument Development and Management

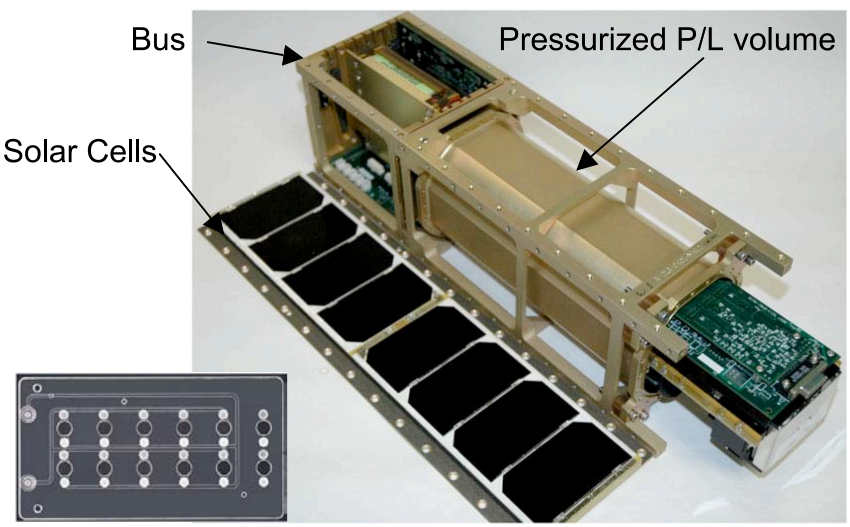
B. Payload & Instrument Examples - GeneSat-1

GeneSat-1 General Description

- Triple cube (3U: 10 x 10 x 35 cm) autonomous spacecraft
- 4W power
- 5 kg total satellite mass
- Magnets for passive attitude control
- Communications systems (C&DH radio + beacon)
- Internal pressurized volume
- Launched as secondary payload

Instrument(s)

- Pressurized volume
- Fine temperature regulation (+/- 0.5°C)
- Well plate format for biology management
- Fluorescent detector(s)
- Light scattering sensor(s)
- Launched December 2006
- Pressurized Payload Volume



GeneSat-1 Sample Card

Potential Future Capabilities

- Unpressurized (exposed) payload volumes
- Articulated solar panels - increased power
- Alternative attitude control techniques - i.e., gravity gradient
- Micropropulsion
- Higher bandwidth downlink - imaging

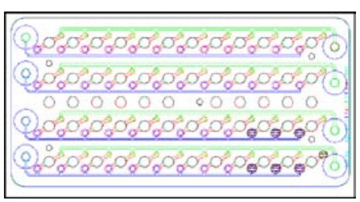
Pharmasat General Description

- Triple cube (3U: 10 x 10 x 35 cm) autonomous spacecraft
- 4W power
- 5 kg total satellite mass
- Magnets for passive attitude control
- Communications systems (C&DH radio + beacon)
- Internal pressurized volume
- Launched as secondary payload
- Launch: August 2008 (planned)

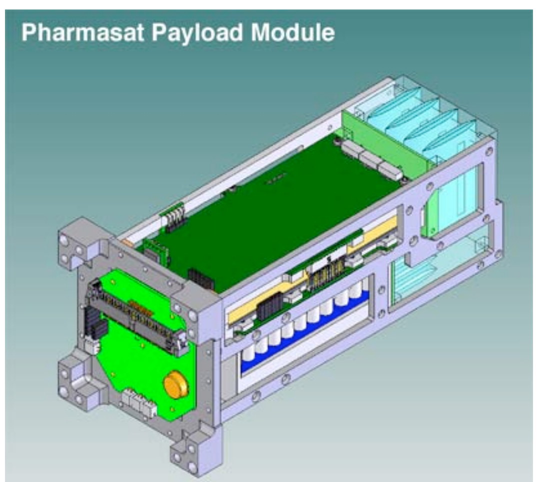
Instrument(s)

- Pressurized volume (larger than GeneSat-1)
- Fine temperature regulation (+/- 0.5°C)
- Wellplate format for biology management (48 wells)
- Luminescence detector(s)
- Light scattering sensor(s)

Pharmasat w/o solar panels



Pharmasat Sample Card



Potential Future Capabilities

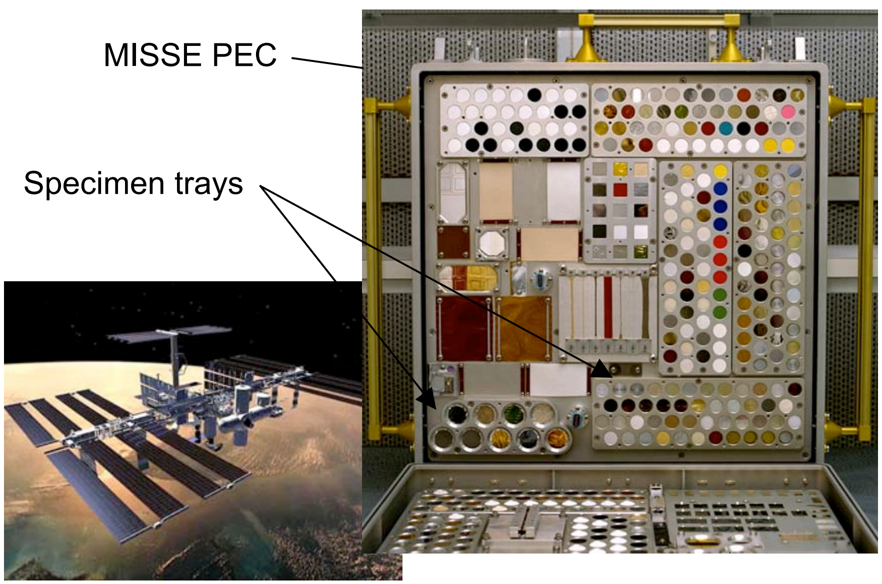
- Articulated solar panels - increased power
- Alternate attitude control technologies
- Higher bandwidth downlink - imaging
- Different sample cards/fluidics
- Alternate optical sensor types

MISSE General Description

- Materials International Space Station Experiment (MISSE)
- Passive Exposure Carrier (PEC)
- Launched via Shuttle and installed on exterior of ISS; returned for post-flight analysis
- Sun facing or shaded surfaces (http://misse1.larc.nasa.gov/)

Instrument(s)

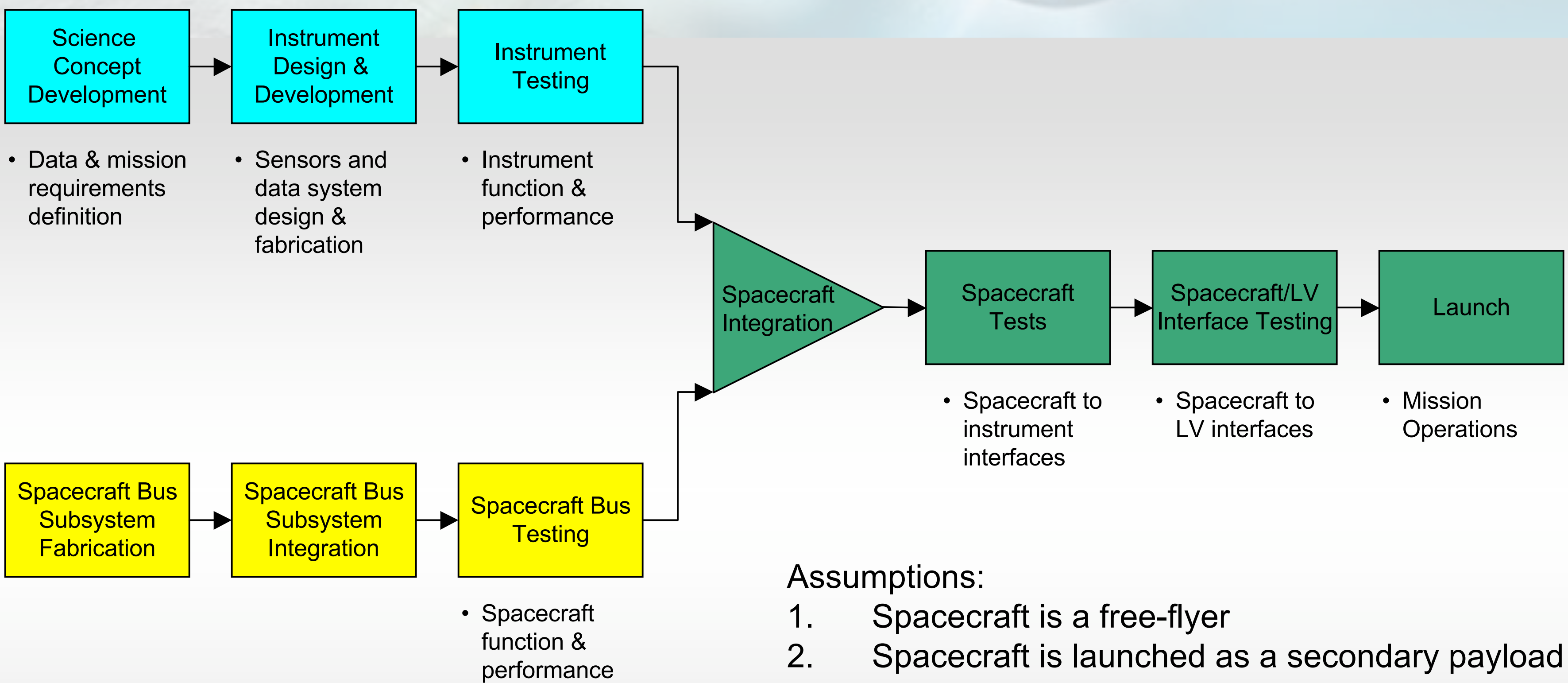
- Trays for mounting of specimens
- Specimens/materials are returned to ground via Shuttle for lab analysis/data reduction



Potential Future Opportunities

- Some future versions of MISSE may have limited power and/or data accommodations
- MISSE experiments are launching/returning approximately yearly

Notional Integration and Testing Flow



Assumptions:

1. Spacecraft is a free-flyer
2. Spacecraft is launched as a secondary payload
3. Bus design is based on or derived from existing spacecraft
4. Instrument development may be performed at PI's or other facility

V. Launch Accommodations & Constraints
A. Launch Vehicles

Minotaur I*

Falcon 1**

Atlas V

Delta IV

Minotaur IV

Taurus

Super Strypi

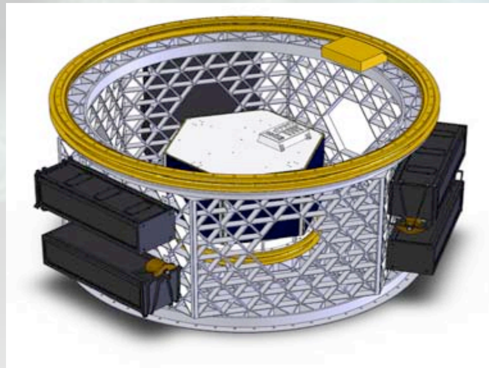
Launch Vehicle	Provider	Launch Sites	Secondary Accommodations
Minotaur I*	USAF (Orbital Sciences)	VAFB Wallops FF	Carries up to 2 PPODs/launch
Falcon 1**	SpaceX	Kwajalein KSC	Secondary Payload Adapter System (SPAS) - carries up to 6 PPODs or another 2° satellite
Atlas V, Delta IV (EELV)	NASA/ULA USAF	KSC VAFB	EELV Secondary Payload Adapter (ESPA) - optional
Minotaur IV	USAF (Orbital Sciences)	Kodiak VAFB; Other TBD	Multiple PPOD accommodations planned (up to 4)
Taurus	NASA (Orbital Sciences)	KSC VAFB	Multiple PPOD accommodations planned (up to 3)
Super Strypi	DoE/DoD Univ. Hawaii	PMRF (Kauaii)	Multiple PPOD accommodations planned (TBD)

** Flown **Planned flight*

V. Launch Accommodations & Constraints

B. Adapters & Interfaces

P-POD



SPASS

ESPA

MISSE

Adapter/Carrier	Spacecraft (2°)	Launch Vehicles
Poly-PicoSat Orbital Deployer (P-POD)	Cubesats (3 x 1U or 3U)	Minotaur I Falcon 1* Minotaur IV* EELV* Super Strypi*
Secondary Payload Adapter and Separation System (SPASS)	Cubesats (1U - 3U) University Nanosats (~50kg)	Falcon 1* *Other TBD*
EELV Secondary Payload Adapter (ESPA)	Various (≤180 kg S/C mass)	Atlas V, Delta IV
Materials International Space Station Experiment (MISSE)	ISS External	Shuttle (ISS)

** Planned capabilities*

Astrobiology Small Payloads

V. Launch Accommodations & Constraints
C. Launch Venues






Wallops Flight Facility, VA	37° 50' N 75° 28' W	Minotaur I & IV* Falcon 1*	• Payload processing facilities • Range services • Launch inclinations: 40.5° only
Vandenberg AFB, CA	34° 44' N 120° 34' W	EELV Minotaur I & IV*	• Payload processing facilities • Range services • Launch inclinations: 56° - 104°
Kodiak Launch Complex, AK	57° 25' N 152° 21' W	Minotaur I	• Payload processing facilities • Range services • Launch inclinations: 64° - 154°
Reagan Test Site, Omelek Island	9° 3' N 167° 45' W	Falcon 1*	• Payload processing facilities • Range services • Launch inclinations: >9°
Kennedy Space Center, FL	28° 27' N 80° 33' W	EELV	• Payload processing facilities • Range services • Launch inclinations: 28.5° - 57°
Pacific Missile and Range Facility, HI	22° 2' N 159° 47' W	Super Strypi*	• Payload processing facilities • Range services • Launch inclinations: 120° only

** Planned launch*

VI. Mission Operations and Management

Missions Operations

Specific documented procedures for detailed operations, including descriptions of transportation and storage criteria for flight hardware units will be documented in a Mission Operations Plan. This plan will outline the sequence of events and operations to be conducted during each ASP mission. All mission operations will be performed and managed by NASA Ames Research Center (ARC) through the Small Spacecraft Office (SSD). The SSD may utilize NASA ARC's Multi-Mission Operations Center and CREST Mission Control Center to perform realtime contact operations with the satellite.

Communications

Communications to/from the spacecraft will be implemented using existing NASA or NASA-provided assets and infrastructure. Mission requirements will dictate the type and methods for spacecraft communication.

Ground Data Systems

Ground data systems are available to receive, store, manage, and forward flight data to the PI's facility for further reduction and processing. Limited data processing may be available on a case-by-case basis, but should not be anticipated. Ground data systems meet all security and NASA policies for management of space-related missions.

Resources baseline for a free-flying spacecraft configuration only based on a 3U-Cubesat platform is provided below for reference.

	Cost Estimate	Comments
Spacecraft Mission		
Program Management	$150-200K	~1.5 Full Time Equivent (FTE) (6-9 mo)
System Engineering	$100-150K	~1 FTE (6-9 mo)
Spacecraft	$350-500K	
Launch Costs	$250-400K	Launch/Adapter/Interfaces Cost + .10 FTE
Reserve	$150-250K	
Total Cost	$1.0-1.5M	
Science/Payload/Instrument		
Science/PI	$150-250K	PI Cost
Instrument/Technology	$150-250K	~1 FTE (6-9 months) + ODC
Science Support	$50--100K	~1 FTE (6-9 months) + ODC
Reserve	$50-100K	
Total Cost	$300K-700K	

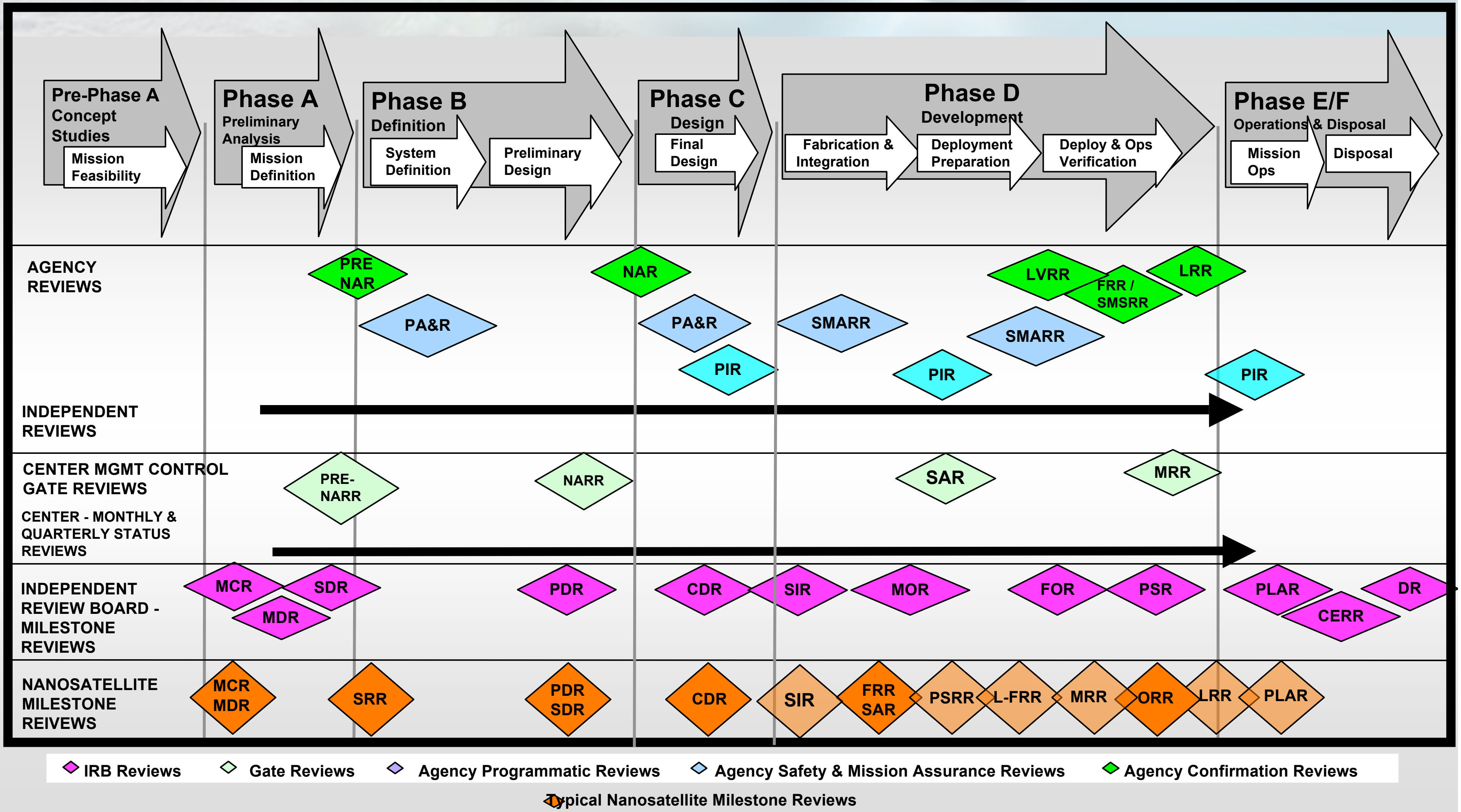
VII. Cost and Schedule Guidelines
B. Typical Nanosat Timeline Schedule

Typical project milestones for a 3U CubeSat platform are provided with estimated timeframes

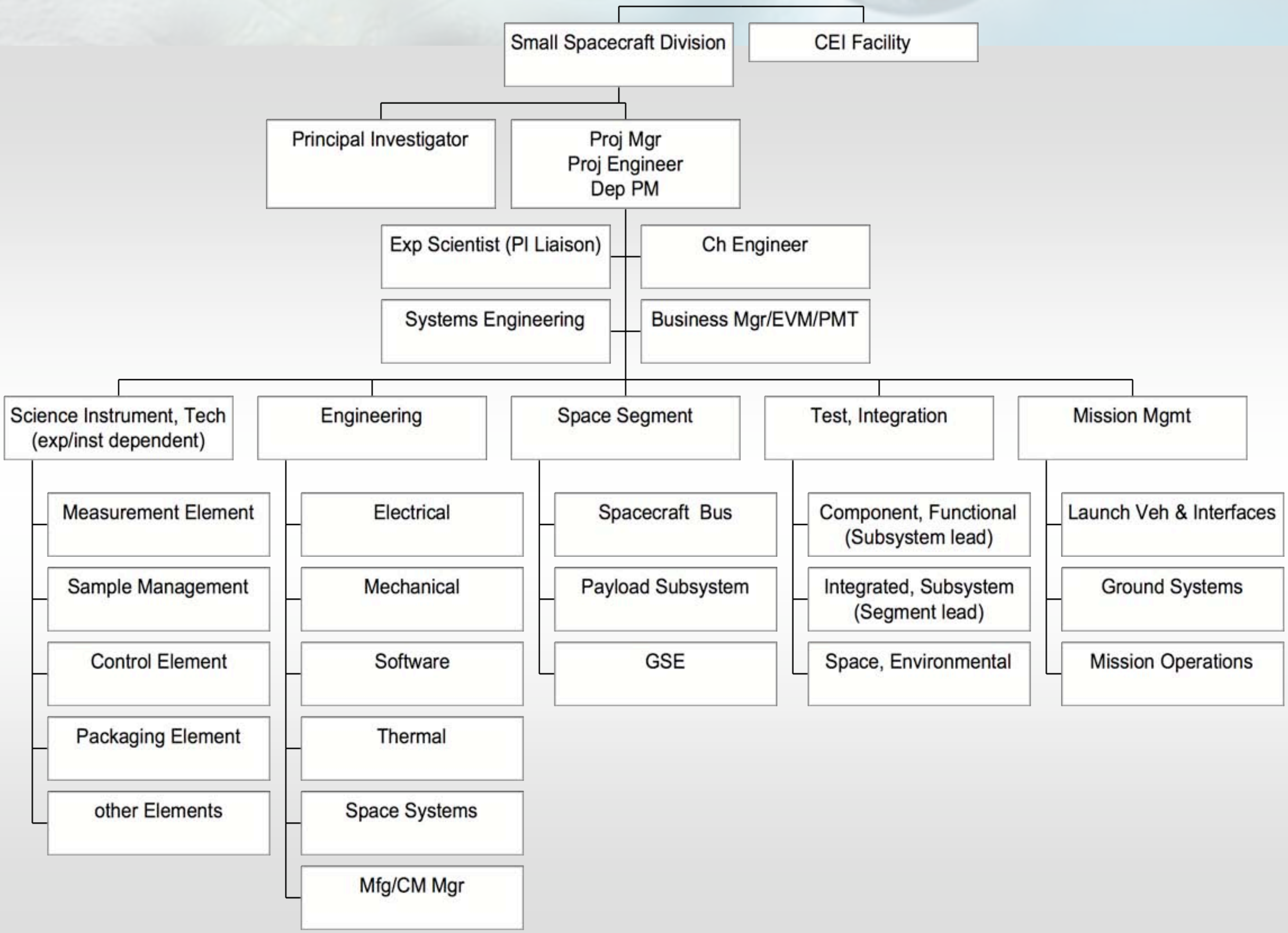
Milestone	Duration
Project Start	
Science/Mission Definition	45 Days
Technology/Instrument Definition	180 Days
SRR	2 Months from Start
Flight Prototype Development	180 Days
PDR	4.5 Months from Start
Spacecraft/Hardware/Software Development	100 Days
CDR	7 Months from Start
Spaceflight Systems Integration and Test	50 Days
FRR	13 Months from Start
Mission Integration	14 Days
MRR	14 Months from Start
Launch	15 Months from Start
Mission Operations / Data Acquisition	45 Days
Post Mission Operations	30 Days
Mission Final Report	1 Year from Mission Complete

VIII. Project Management
A. Project Life Cycle Control Gates

Project management will be generally implemented following Project Life Cycle guidelines as defined by NASA Space Flight Program and Project Management Requirements NPR 7120.5D and NASA-Ames APR 7123.1. The figure below illustrates standard Project Life Cycle Elements elements for space flight projects. Together with the OBS, and WBS, and with specificschedule and milestone tailoring for the requirements of the PI, Project, Mission, and Customer, a complete project management plan can be implemented. Specific schedule is dependent on project scope, mission requirements, and programmatic approval.



The figure below illustrates a typical level 2 Organizational Breakdown Structure (OBS) elements for space flight projects. Project function responsibilities can be defined and managed using this structure.



Project management will be implemented following the Work Breakdown Structure (WBS) as defined by NASA Space Flight Program and Project Management Requirements NPR 7120.5D. The figure below illustrates standard level 2-3 WBS elements for space flight projects. Project task, and cost management can be defined using this structure

Generic Project WBS (per 7120.5D)

Project Management 01
- 1.1Business Mgt
- 1.2 Proj Organiz.
- 1.3 Reviews
- 1.4 Facilities
- 1.RE Reserves

Systems Engr 02
- 2.1 Flt Sys Architecture
- 2.2 Grd Sys Definition
- 2.3 Design Trades
- 2.3 Risk Management
- 2.4 Software Sys Engr
- 2.5 Configuration Contr
- 2.6 Requirements Mgt
- 2.7 Interface Control
- 2.8 Test Plans
- 2.9 Launch Sys Engr
- 2.10 Project V&V Plan

Science/ Technology 04
- 4.1 Science Mgmt
- 4.2 Sci Implement
- 4.3 Science Ops
- 4.3 Data Analysis
- 4.4 Science Facil

Safety & M.A. 03
- 3.1 Success Criteria
- 3.2 Safety Practices
- 3.3 Mission Assurance Assessment

Payload Systems 05
- 5.1 P/L Sys Mgmt
- 5.2 P/L Sys Engr
- 5.3 Instruments
- 5.4 P/L Data Handling System
- 5.5 P/L Software

Ground Sys 09
- 9.1 ARC MMOC Grd Sys
- 9.1.1 H/W
- 9.1.2 S/W
- 9.1.3 Network/Facil
- 9.2 Remote Grd Sys
- 9.2.1 H/W
- 9.2.2 S/W
- 9.2.3 Network/Facil

Flight System 06
- 6.1 Flt Sys Mgmt
- 6.2 Flt Sys Engr
- 6.3 Flt Sys Prod Assurance
- 6.4 Power Subsys (Design,*Develop/ Purchase*,Test)
- 6.5 C&DH SubSys
- 6.6 Telecom SubS
- 6.7 Struct SubSys
- 6.8 Therm SubSys
- 6.9 Propuls SubSys
- 6.10 ADCS SubSys
- 6.11 Harness(es)
- 6.12 Flt Software
- 6.13 Fly Sys Materials & Processes
- 6.14 Flt Sys Testbeds
- 6.15 Grd Suppt Equip
- 6.16 De-Orbit Option

Launch Vehicle/Serv 08
- 8.1 Launch Ops Oversight
- 8.2 Launch Integr Support

Systems I&T 10
- 10.1 I&T Facilities
- 10.2 I&T Equip
- 10.3 I&T Software
- 10.4 Test Activities
- 10.5 V&V Activities

Mission Ops 07
- 7.1 Ops Mgmt
- 7.2 Tracking
- 7.3 Commanding
- 7.4 Receiving/ Processing Data
- 7.5 Maneuvering
- 7.6 Disposal
- 7.7 Training

E&PO 11
- 11.1 Mgmt & Coord
- 11.2 Formal E/O
- 11.3 Informal E/O
- 11.4 Public Outreach
- 11.5 Media Support
- 11.6 Web-site Devel

Astrobiology Small Payloads

IX. Example Mission Scenarios
A. PharmaSat (MicroSat-1) - Biological

PharmaSat

PI: Dr. Michael R. McGinnis, UTMB
PM: Charlie Friedericks, NASA ARC
Engineering Team: NASA ARC, ASRC, Jacobs, UARC
Website URL:pending

Objectives:

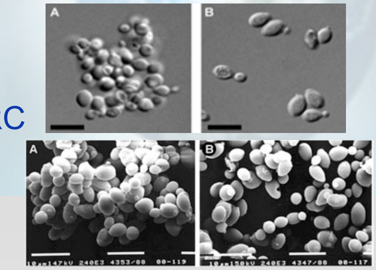
- A PI led investigation to characterize the effect of microgravity upon yeast susceptibility to antifungal drugs for countermeasure development
- "Proof-of-Concept" demonstrating the use of a MicroSat development in order to achieve peer reviewed research

Relevance/Impact:

- Directly addresses questions concerning how the space flight environment alters yeast resistance to the azole antifungal agent voriconazole; microgravity and modeled microgravity data suggest that resistance to azoles is increased
- Important implications for the prevention and management of fungal infections that may occur during space exploration
- Provides an alternative method to conduct space based life science studies.

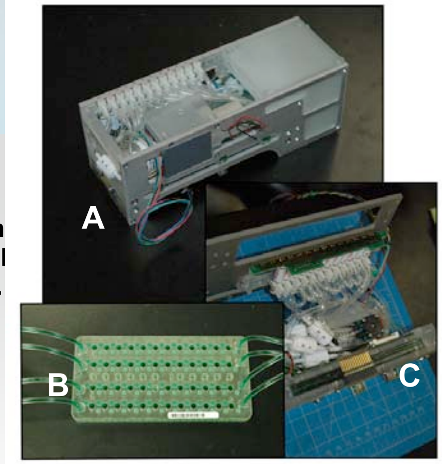
Development Approach:

- Experimental design is based upon an internationally recognized *in vitro* laboratory testing method
- Statistical analysis of the *in situ* data will be based upon the methods used to analyze longitudinal data
- PharmaSat vehicle design and management leverages upon the extensive technology development program and recent flight heritage of GeneSat-1



***Saccharomyces cerevisiae* grown at 25ºC, 72h. Panel A HARV, panel B gravity control. Bars are 10mm.**

PharmaSat Flight Article



A -PharmaSat Payload, B-Fluidics Card, C - Fluid Delivery System

Resource Requirements/Mission Overview

Total Mass (Satellite + PPOD)	7.6 kg (5.1+ 2.5 kg)
Satellite Power (on-orbit average)	4 - 5 W
Satellite Volume	3 "Cubes" (14" x 4" x 4") incl beacon
Science Data/Command Up/Downlink E/PO Beacon/Data Downlink	~200 kB/day, ISM band (2.4 GHz) Amateur band (~437 MHz)
Launch Readiness Date	NET11/2008
Mission Duration (spacecraft design life);	$\geq$ 21 days (Experiment Duration ~ 100 hours)
Orbit Altitude	460 km
Orbit Inclination	40.5°
Launch Vehicle	Minotaur I (TacSat-3 Primary)

Project Life Cycle Schedule

Milestones	PDR	CDR	FRR	Launch	Ops	Final Report
Actual/ Baseline	**2/07**	**4/07**	**4/08**	**NET 11/08**	**Launch + 3MO**	**Return + 12m**

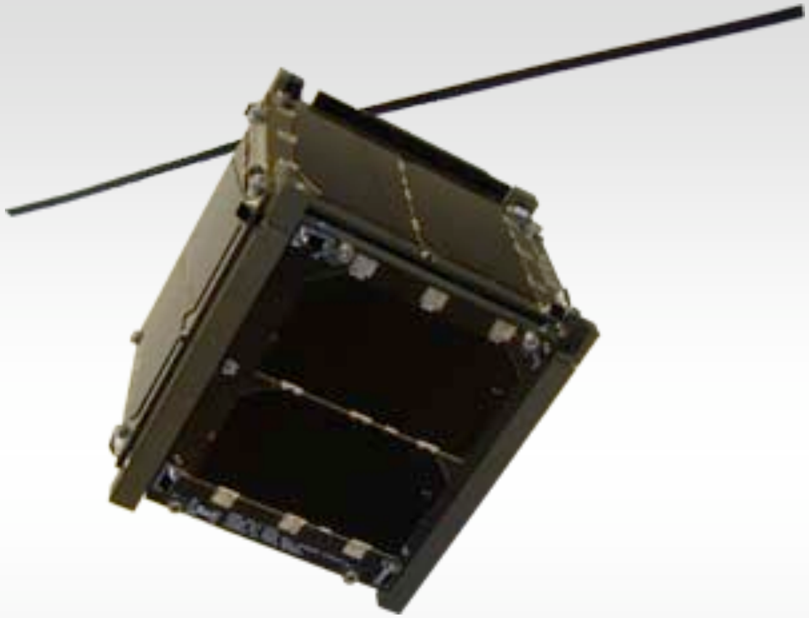
School: *California Polytechnic State University at San Luis Obispo*
Launch Date: DNEPR2 04/17//07 Launch
Website URL: http://cubesat.atl.calpoly.edu/

Objectives:
Attitude Determination and Control using 2-Axis Magnetometers and Magnetorquers

Relevance/Impact:
The primary mission of CP3 was to implement an attitude control system using only magnetic torquers embedded within the side panels. Attitude determination was performed using the two axis magnetometers on each side panel.

As with all of CalPoly CubeSats, a primary mission is also education. This project was student-run, and the aim was to design, build, launch and operate a satellite with as much student involvement as possible.

Development Approach:
The standard bus developed for CP2 was used for CP3 to validate the concept of a standard CubeSat bus to accommodate any payload.



CalPoly CP3 Satellite

Name: *Libertad 1*
Design and Fabrication*: Universidad Sergio Arboleda*
Launch Date: *DNEPR 03/27/07, Kazakhastan*
Website URL*: http://www.usergioarboleda.edu.co/proyecto_espacial/*
(English download available)

Objectives:
Technology demonstration

Relevance/Impact:
First Pumpkin user; first Colombian satellite to orbit the Earth.

Components:
2nd-generation CubeSat Kit structure
2nd-generation CubeSat Kit electronics
Pumpkin Salvo v3 RTOS
StenSat Group VHF/UHF Module
User-designed EPS, antennas
Batteries only (no working Solar Panels)

Used a telemetric payload for communication with the ground.

Pumpkin, Inc 1U CubeSat

References:

NASA Astrobiology Roadmap, September 2003 < http://astrobiology.arc.nasa.gov/roadmap>
Genesat-1 Technology Demonstration Mission http://genesat.arc.nasa.gov/

Contacts:

For technical information regarding Astrobiology Small Payload / Small Satellite Opportunities

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